ASSESSMENT OF THE WATER SITUATION ASSESSMENT MODEL (WSAM)

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Abstract

The Department of Water Affairs and Forestry (DWAF) developed the Water Situation Assessment Model (WSAM) as a macro-scale water resource planning tool. The model provides users with a systematic approach for reconnaissance-level planning and scenario testing, while efficiently managing large volumes of information. The purpose of WSAM is to summarise information, on the availability, supply and utilisation of water resources at a national, regional and catchment level for both current and projected future situations.

Considerable testing and validation of various WSAM sub-models and algorithms was undertaken as part of the model development process. Most recently, an independent user assessment of WSAM was initiated through the Olifants River Pilot Study that was undertaken by the DWAF Directorate: National Water Resource Planning.

This paper provides feedback on the status of WSAM (3.003), based on the results from this application study as well as additional technical investigations and refinement work.

Keywords: *WSAM, WRYM, Macro-scale planning, Assessment, Olifants River Catchment.*

1. Introduction

1.1 Background

The Department of Water Affairs and Forestry (DWAF) developed the Water Situation Assessment Model (WSAM) as a macro-scale planning tool for water resources. It provides users with a systematic approach for undertaking reconnaissance-level planning and scenario testing while managing large volumes of information. The purpose of WSAM is to summarise information, for the current and projected future situations, on the availability, supply and utilisation of water resources at a national, regional and catchment level.

Considerable testing and validation of various WSAM sub-models and algorithms have been undertaken as part of the ongoing model development process. Most recently, the *Olifants River Pilot Study* was undertaken by the DWAF Directorate: National Water Resource Planning for the purpose of testing the model independently, based on a water resource system that had been analysed with rigorous hydrological and system analysis methods (Dempster et al 2002). The Pilot Study commenced in 2003 and focussed on the validation of WSAM by direct application of the model in the upper Olifants River Catchment. The study was completed in May 2004 and provided a comparison of WSAM and WRYM results.

1.2. WSAM Base-Data

The WSAM base-year catchment information (base-data) set consists of more than 150 input parameters for each of the about 2000 DWAF-defined quaternary catchments in the RSA. Each of these also includes more than 5 metadata fields to keep track of the origin and accuracy of the data value. The base-data set is an extremely valuable source of information for water resources modelling studies.

The original base-data set represents the situation at the 1995 development level and was populated based on information from the Water Resources Situation Assessments, a series of reconnaissance-level assessment studies undertaken at the scale of Water Management Area (Smook AJ, et al 2002). The database is regularly being improved and updated as new information becomes available.

1.3 WSAM Conceptual Logic

The modelling approach adopted for WSAM is set within an overall conceptual framework, which is based on the primary objective of reconciling the water resources and water requirements for defined catchment areas, by means of an annual balance undertaken at an assurance level of 98 % (equivalent to a recurrence interval of failure of 1 in 50 years). The result can be either a deficit or a surplus, depending on the specific circumstances in the catchment under consideration.

WSAM is made up of several sub-models, each of which is described by a set of mathematical equations designed to model a specific component of the catchment balance. The sub-models are executed in a fixed sequence, dictated by the dependency of one sub-model on the calculated results of another, as well as water allocation priorities adopted for the user groups involved. The sub-models and the sequence in which they are executed is listed below:

1) Bulk water requirement.
2) Urban water requirement.
3) Rural water requirement.
4) Irrigation water requirement.
5) Commercial forestry.
6) Alien vegetation.
7) Dry-land crops.
8) Groundwater.
9) Human reserve.
10) Reservoir characteristics.
11) Inter-basin transfers.
12) Sedimentation.
13) Virgin incremental yield.
14) Enhanced incremental yield.
15) Disturbed incremental yield.
16) Run-of-river yield.
17) River losses.
18) Conversions of water requirements to the equivalent 98 % assurance.
19) Hydropower.
20) Ecological water requirements.
21) Yield balance.

For a detailed description of each of the sub-models refer to the *WSAM Theoretical Guide* (DWAF, 2002).

The general modelling approach adopted for WSAM revolves around an annual balance of water resources and water requirements undertaken for discreet catchment areas. This is based on certain key concepts as discussed below:

- WSAM is intended as a macro-scale planning tool and assumes efficient use of the water resources as well as a constant provision of water supplies and does not take into account variations in operatin g rules for the management of water resources during drought periods. However, certain operational principles are incorporated in the model in a generic way, such as supply priorities and the cascading of surplus water to downstream catchments.
- The catchment balance is undertaken based on annual data and in order to achieve realistic yield results, the model makes use of storage-draft-frequency characteristic curves that take account of the complex dynamics of water resource systems. These curves have been derived based on detailed monthly time-series simulation analyses and are applied to accommodate a variety system development options.
- The quaternary catchment is used as the basic spatial unit for the model and all balance calculations for a catchment are undertaken at a nodal point representing its outlet. This implies that water sources associated with a quaternary catchment are lumped together and are assumed to be available to all water users in that catchment (depending on the availability of water an d supply priorities). This approach is appropriate for most macro-scale planning purposes.
- The catchment balance is undertaken at a standard assurance level of 98 %. For this purpose, water requirements at other assurance levels are adjusted to represent an equivalent volume at the 98 % assurance. This is achieved by using a set of scaling factors which were derived from the firm yield characteristics of the catchment under consideration. However, the base-yield component of the yield-reliability curve is not fully accounted for. This means that in some cases the estimates of water resources availability might differ slightly depending on the yield-reliability characteristics and mix of users associated with the catchment in question.

2. Comparison of WSAM And WRYM results

The study area adopted for the assessment of WSAM incorporates the Olifants River catchment upstream of Loskop Dam (tertiary catchments B11, B12 and B20 and quaternary catchment B32A) (Figure 1). This area was selected because detailed information from hydrological and system analysis studies was available and the complexity of the area is such that it serves to test most of the WSAM components.

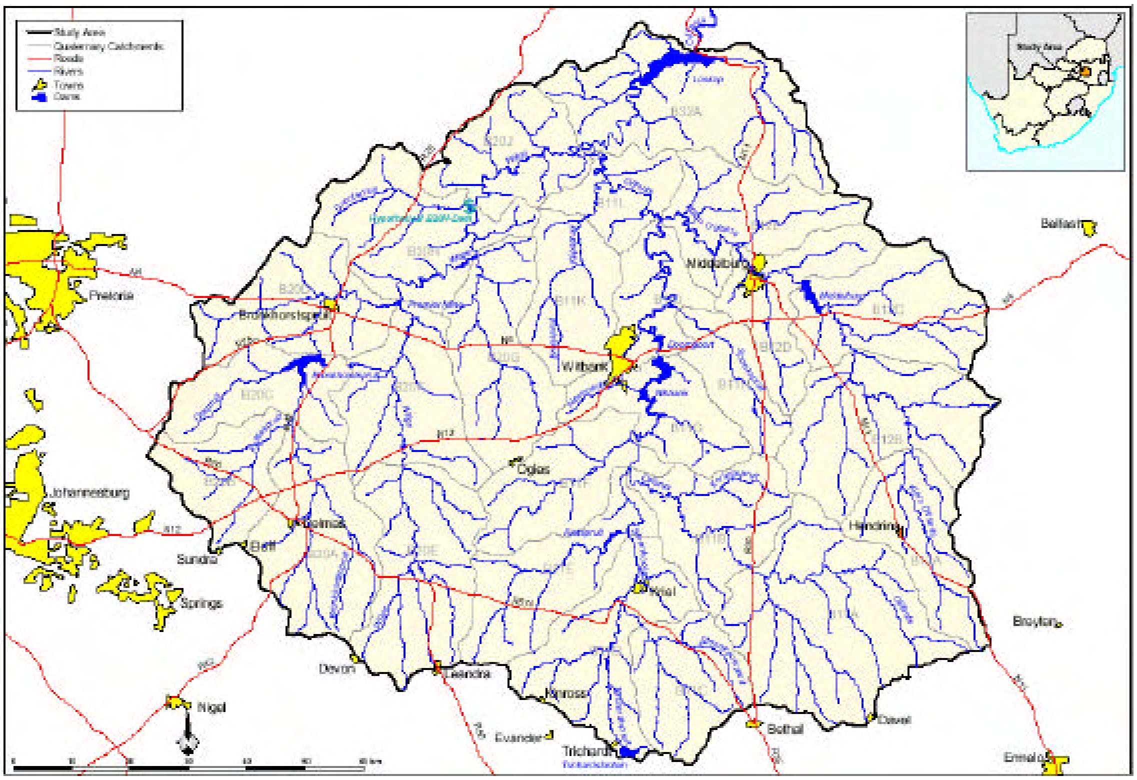


Figure 1: Olifants River catchment upstream of Loskop Dam

2.1 General

A detailed evaluation was made of the relative accuracy of WSAM results by comparing it to those from the Water Resources Yield Model (WRYM) for the Olifants River catchment. This involved a process whereby a comparison is made, at a particular point in a river, of the yield obtained from a WRYM analysis and the equivalent value as estimated using WSAM. The sites at which comparisons were made included the four major dams in the Olifants River system, namely Bronkhorstspruit Dam, Witbank Dam, Middelburg Dam and Loskop Dam, as well as selected sites in the upper Vaal River catchment.

2.2 Methodology

The comparison of WSAM and WRYM results was undertaken based on the following methodology:

- Identify the target catchment for validation. This catchment lies upstream of a particular point in a river at which yields are to be compared.
- Adjust the WRYM system configuration data files and demand files to represent the specific scenario to be analysed.
- Undertake parameter synchronisation. This is central to the methodology of validation and involves the adjustment of WSAM parameter values for the target catchment to ensure that the input data resembles as closely as possible that used for the WRYM analysis.
- Verify the WRYM and WSAM configurations and check that the scenario under consideration is correctly represented.
- Use the verified WRYM setup and determine the long-term stochastic yield at the 98 % assurance (1 in 50-year risk of failure), based on 201 76-year stochastically generated stream flow sequences.
- The final step in the validation involved a comparison of yields. The WRYM 98 % assurance yield is compared with the value of the WSAM yield balance parameter yYYBo.

A standard approach was adopted to estimate the yields of dams for all analyses undertaken with both the WRYM and WSAM. Yields were determined at upstream dams first (Bronkhorstspruit, Witbank and Middelburg). In a second modelling run, the yield of each upstream dam was then imposed on that dam as a demand, before the remaining yield was determined at the downstream dam (Loskop). The downstream yield therefore represents the incremental resource, and not that of the system as a whole.

In order to test the various sub-models that are incorporated in WSAM, a variety of comparisons were undertaken, each of which was based on an alternative system configuration, designed to highlight the effect of a particular sub-model. The first is a base situation scenario, which serves as a reference. It represents a basic system, incorporating only the four major dams mentioned above and no other developments. Each of the other scenarios were derived from the base situation scenario, but incorporates an additional system component to be tested. The effect of the system component in question was evaluated by comparing results with those of the base situation scenario. The system components that were considered (in various combinations) include:

- major dams,
- ecological water requirements,
- minor dams,
- irrigation water requirements,
- stream flow reduction,
- losses, and
- inter-basin transfers.

2.3 Scenarios

In Sections 2.3.1 to 2.3.10 below, each of the eight scenarios (I to VIII) is described and results are evaluated and discussed.

2.3.1 Base situation

This scenario serves as a basis for the configuration of subsequent scenarios as well as a reference for evaluating results. Scenario I represents the basic system, incorporating major dams Bronkhorstspruit, Witbank, Middelburg and Loskop with evaporation and natural hydrology. All other system components identified in section 2.2 are excluded.

The final analysis results for Scenario I are summarised in Table 2-1 and it can be seen that the yield estimates from the WRYM and WSAM analyses correlate extremely well (discrepancies are less than 4%). These results serve to confirm the appropriateness and accuracy of the storage-draft-frequency curves implemented in WSAM for the test catchments; the configuration of Scenario I excludes the impacts of other system components on the yield. The observed differences in the WRYM and WSAM results are attributed to the smoothing-effect introduced as part of the process to derive storage-draft-frequency curve characteristics, which involved curve-fitting to system analysis yield results.

Dam name	Location (quaternary catchment)	WRYM Yield at 98 % assurance (million m^3/a)	WSAM Yield balance yYYBo (million m^3/a)	Difference (%)
Scenario I(Base situation)				
Bronkhorstspruit	B20C	24.0	23.3	-3.0 %
Witbank	B11G	51.6	51.3	-0.6 %
Middelburg	B12C	22.8	22.7	-0.5 %
Loskop	B32A	167.0	173.2	3.7 %

Table 2.1 Final Analysis Results for Scenario I

2.3.2 Combinations of dam sizes

This scenario serves to test the results from WSAM for different combinations of dam sizes, with specific focus on the impact of upstream storage on the yield of downstream dams. Scenario II incorporates major dams at the Bronkhorstspruit, Witbank, Middelburg and Loskop sites with evaporation and natural hydrology. All other system components are excluded. Various dam size combinations are defined in terms of six separate scenarios, referred to as **Scenario II1** to **II6**. The final analysis results for Scenario II1 to II6 are summarised in Table 2-2.

Dam name	Location (quaternary catchment)	WRYM Yield at 98 % assurance (million m^3/a)	WSAM Yield balance yYYBo (million m^3/a)	Difference (%)
Scenario II1 (Different combinations of dam sizes: Loskop 50 %; Others 100 %)				
Bronkhorstspruit	B20C	24.0	23.3	-3.0 %
Witbank	B11G	51.6	51.3	-0.6 %

Dam name	Location (quaternary catchment)	WRYM Yield at 98 % assurance (million m^3/a)	WSAM Yield balance yYYBo (million m^3/a)	Difference (%)
Middelburg	B12C	22.8	22.7	-0.5 %
Loskop	B32A	121.3	132.4	9.1 %
Scenario II2 (Different combinations of dam sizes: Loskop 150 %; Others 100 %)				
Bronkhorstspruit	B20C	24.0	23.3	-3.0 %
Witbank	B11G	51.6	51.3	-0.6 %
Middelburg	B12C	22.8	22.7	-0.5 %
Loskop	B32A	197.0	196.3	-0.4 %
Scenario II3 (Different combinations of dam sizes: Loskop 100 %; Others 50 %)				
Bronkhorstspruit	B20C	18.8	18.8	0.0 %
Witbank	B11G	35.7	36.2	1.3 %
Middelburg	B12C	18.1	18.3	1.1 %
Loskop	B32A	175.8	173.2	-1.5 %
Scenario II4 (Different combinations of dam sizes: Loskop 100 %; Others 150 %)				
Bronkhors tspruit	B20C	27.8	26.1	-6.1 %
Witbank	B11G	61.5	61.0	-0.8 %
Middelburg	B12C	25.7	25.8	0.4 %
Loskop	B32A	165.1	173.1	4.8 %
Scenario II5 (Different combinations of dam sizes: Witbank 50 %; Others 100 %)				
Bronkhorstspruit	B20C	24.0	23.3	-3.0 %
Witbank	B11G	35.7	36.1	1.1 %
Middelburg	B12C	22.8	22.7	-0.5 %
Loskop	B32A	173.2	173.2	0.0 %
Scenario II6 (Different combinations of dam sizes: Witbank 150 %; Others 100 %)				
Bronkhorstspruit	B20C	24.0	23.3	-3.0 %
Witbank	B11G	61.6	61.0	-1.0 %
Middelburg	B12C	22.8	22.7	-0.5 %
Loskop	B32A	166.2	173.2	4.2 %

Table 2.2 Final Analysis Results for Scenario II1 to II6

The estimates of yield from the WRYM and WSAM analyses correlate well. The absolute difference at the catchment outlet (Loskop Dam) is 3.3% on average with a maximum value of 9.1%. The results for Loskop Dam show that the WSAM methodology of accounting for upstream storage in estimating the yield of dams is valid for a variety of combinations of dam sizes. Slight overestimation does seem to occur when the downstream storage is small relative to the dams upstream (see results of Scenarios II1 and II4).

The WSAM yield estimates for scenario II3 to II6 do not vary with changes in upstream storage as expected; a constant value of 173.2 million m^3/a occurs for Scenarios I, II3, II4, II5 and II6 despite variation in upstream storage. However, yield estimates remain acceptable and within 5% of that from the WRYM analysis. The reason for the identical WSAM result is related to the fact that WSAM employs two alternative methods to account for upstream storage in estimating the yield of major dams. One of the methods, referred to as the "Incremental Yield" -method, applies to cases where the size of upstream storage is large relative to the available runoff. It is based on the assumption that the downstream dam does not benefit from upstream dam spills, hence the identical results for the above scenarios. Detailed descriptions of the yield accounting methods used in WSAM are given in the *WSAM Theoretical Guide* (DWAF, 2002).

2.3.3 Ecological water requirements

This scenario was designed to test WSAM results for the impact on yield of incorporating ecological water requirements. Scenario III incorporates the major dams with evaporation and natural hydrology as in Scenario I. In addition ecological requirements are incorporated in the form of *In-stream Flow Requirements* (IFRs) based on the *Ecological Management Class* (EMC) D. IFRs were determined for IFR sites situated downstream of each major dam in the system using the Hughes Desktop model (Hughes 1999).

The final analysis results for Scenario III are summarised in Table 2-3. The yield estimates from the WRYM and WSAM analyses correlate well with a absolute differences are less than 4%.

A further comparison was made by subtracting the yield estimates obtained from Scenario I (see Section 2.3.1) from the corresponding values in Scenario III. This provides an estimate of the actual impact of the IFR on yield. Such a calculation

was undertaken for both the WRYM and WSAM results which is included in Table 2.4. WSAM was found to overestimates the impact of the IFR on yield in total by 2.7 Mm^3/a which is a difference of only 4.5 %.

Dam name	Location (quaternary catchment)	WRYM Yield at 98 % assurance (million m^3/a)	WSAM Yield balance yYYBo (million m^3/a)	Difference (%)
Scenario III (Ecological requirements)				
Bronkhorstspruit	B20C	17.6	18.0	2.0 %
Witbank	B11G	39.4	40.9	3.9 %
Middelburg	B12C	17.6	17.2	-2.2 %
Loskop	B32A	131.0	131.9	0.6 %

Table 2.3 Final Analysis Results for Scenario III

Dam name	Location (quaternary catchment)	WRYM Impact on yield at 98 % assurance (million m^3/a)	WSAM Impact on yield balance yYYBo (million m^3/a)	Difference (million m^3/a)
Bronkhorstspruit	B20C	24.0 - 17.6 = 6.4	23.3 - 18.0 = 5.3	-0.9
Witbank	B11G	51.6 - 39.4 = 12.2	51.3 - 40.9 = 10.4	-1.8
Middelburg	B12C	22.8 - 17.6 = 5.2	22.7 - 17.2 = 5.5	-0.3
Loskop	B32A	167.0 - 131.0 = 36.0	173.2 - 131.9 = 41.3	5.3
Total		59.8	62.5	2.7

Table 2.4 Impact of IFR on Yield.

2.3.4 Catchment developments

This scenario was designed to test the impact of catchment developments on WSAM results, with specific focus on minor dams and irrigation. Scenario IV incorporates the four major dams with evaporation and natural hydrology. Catchment developments were analysed in two separate combinations, as follows:

- Scenario IV1: Based on Scenario I (which represents the basic system with major dams and no other developments), with minor dams included.
- Scenario IV2: Based on Scenario IV1, with irrigation set equal in the WSAM to the WRYM.

The final analysis results for Scenario IV are summarised in Table 2-5 It can be seen that the results from the WRYM and WSAM analyses correlate well. Notably, however, it can be observed that for these specific conditions WSAM generally estimates a higher impact on yield of irrigation than the WRYM. This is possibly due to the fact that WSAM makes use of an assurance table to factor the irrigation demand to an equivalent 98% assured requirement where as the WRYM will meet demand depending on the availability of water. Information on the assurance of supply to users upstream of the defined outlet yield channel is not readily available from the WRYM. It is possible that the observed discrepancies are explained by the supplies in the WRYM being provided at a different level of assurance than in WSAM. This was not checked in the study.

Dam name	Location (quaternary catchment)	WRYM Yield at 98 % assurance (million m^3/a)	WSAM Yield balance yYYBo (million m^3/a)	Difference (%)
Scenario IV1 (Base situation with minor dams)				
Bronkhorstspruit	B20C	20.9	21.2	1.4 %
Witbank	B11G	42.7	45.0	5.4 %
Middelburg	B12C	16.4	16.4	0.2 %
Loskop	B32A	159.0	173.4	9.0 %
Scenario IV2 (Scenario IV1 with irrigation)				
Bronkhorstspruit	B20C	17.7	16.4	-7.1 %
Witbank	B11G	40.2	41.5	3.2 %
Middelburg	B12C	13.2	12.6	-4.5 %
Loskop	B32A	142.4	146.2	2.6 %

Table 2.5 Final Analysis Results for Scenario IV

2.3.5 Stream flow reduction

This scenario was designed to test WSAM results for the impact on yield of incorporating stream flow reduction caused by commercial forestry. Scenario V is based on scenario I with hypothetical areas of commercial forestry introduced in a range of quaternary catchments upstream of Loskop Dam. Two individual scenarios were analysed to test the impact of forestry, as described below:

- Scenario V1: Based on Scenario I, with forestry;
- Scenario V2: Based on Scenario V1, with an additional hypothetical major dam introduced downstream of Bronkhorstspruit Dam at the outlet of quaternary catchment B20H. The analysis allows for the impact of forestry to be tested on three dams that lie in series (Bronkhorstspruit, the B20H-dam and Loskop).

The final analysis results for Scenarios V1 and V2 are summarised in Table 2-6. It can be seen that discrepancies in the results from the WRYM and WSAM analyses fall within a range of 10%, and differ on average by only 3.2%.

A further comparison was made by subtracting the yield estimates obtained from Scenario I (see Section 2.3.1) and Scenario V1 to obtain an estimate of the actual impact on yield of forestry. Such a calculation was undertaken and the results for both the WRYM and WSAM can be seen in Table 2.7. In all cases the results indicate a good correlation.

Dam name	Location (quaternary catchment)	WRYM Yield at 98 % assurance (million m^3/a)	WSAM Yield balance yYYBo (million m^3/a)	Difference (%)
Scenario V1 (Base situation with forestry)				
Bronkhorstspruit	B20C	20.5	19.8	-3.7 %
Witbank	B11G	45.7	45.4	-0.7 %
Middelburg	B12C	22.8	22.7	-0.5 %
Loskop	B32A	153.2	158.0	3.1 %
Scenario V2 (Scenario F1 with 3 dams in series)				
Bronkhorstspruit	B20C	20.5	19.8	-3.7 %
Witbank	B11G	45.7	45.4	-0.7 %
Middelburg	B12C	22.8	22.7	-0.5 %
B20H-dam	B20H	49.6	48.7	-1.8 %
Loskop	B32A	115.8	105.2	-9.2 %

Table 2.6 Final Analysis Results for Scenario V

Dam name	Location (quaternary catchment)	WRYM Impact on yield at 98 % assurance (million m^3/a)	WSAM Impact on yield balance yYYBo (million m^3/a)	Difference (million m^3/a)
Bronkhorstspruit	B20C	24.0 - 20.5 = 3.5	23.3 - 19.8 = 3.5	0.0
Witbank	B11G	51.6 - 45.7 = 5.9	51.3 - 45.4 = 5.9	0.0
Middelburg	B12C	22.8 - 22.8 = 0.0	22.7 - 22.7 = 0.0	0.0-
Loskop	B32A	167.0 - 153.2 = 13.8	173.2 - 158.0 = 15.2	1.4
Total		23.2	24.6	1.4

Table 2.7 Impact of forestry on yield.

2.3.6 Losses

This scenario was designed to test WSAM results for the impact on yield of river losses and evaporation losses from the water surface of dams. Four individual scenarios were analysed to test the impact of losses, as described below.

- Scenario VI1: Based on Scenario I, modelled without evaporation losses from Loskop Dam.
- Scenario VI2: Based on Scenario I, with Loskop Dam modelled with a full supply capacity of 500 % of its mean annual runoff (MAR). All dams were modelled with evaporation losses.
- Scenario VI3: The same as Scenario VI2, modelled without evaporation losses from Loskop Dam.
- Scenario VI4: Based on Scenario 1, modelled with a river loss of 10 million m^3/a downstream of Middelburg Dam.

The final analysis results for Scenarios VI1 to VI4 are summarised in Table 2-8. It can be seen that from the results from the WRYM and WSAM analyses that all of the differences are within a 10% range.

Dam name	Location (quaternary catchment)	WRYM Yield at 98 % assurance (million m^3/a)	WSAM Yield balance yYYBo (million m^3/a)	Difference (%)
Scenario VI1 (Loskop without evaporation losses)				
Loskop	B32A	181.4	187.6	-3.4 %
Scenario VI2 (Loskop 500 % of MAR, with evaporation losses)				
Loskop	B32A	284.0	255.9	-9.9 %
Scenario VI3 (Loskop 500 % of MAR, without evaporation losses)				
Loskop	B32A	383.0	354.5	-7.5 %
Scenario VI4 (Base situation with river losses downstream of Middelburg Dam)				
Loskop	B32A	179.8	173.2	-3.7 %

Table 2.8 Final Analysis Results for Scenario VI

2.3.7 1995 development situation

This scenario was designed to configure WSAM for the 1995 development situation, enabling direct comparison with results from the detailed WRYM system analysis undertaken for the *Upper Olifants River*-study (BKS, JA and WMB, 2002). The system was configured in accordance with the *Base Scenario* of the *Upper Olifants River*-study and incorporates all catchment developments at the 1995 development level.

The final analysis results for Scenario VII are summarised in Table 2-9. The results from the WRYM and WSAM analyses are all within the 10% range. The differences can be attributed to the fact that it seems for this specific conditions W SAM generally estimates a higher impact on yield by irrigation than the WRYM. (Refer to section 2.3.4)

Dam name	Location (quaternary catchment)	WRYM Yield at 98 % assurance (million m^3/a)	WSAM Yield balance yYYBo (million m^3/a)	Difference (%)
Scenario VII (1995 developme nt situation)				
Bronkhorstspruit	B20C	18.5	16.7	-9.5 %
Witbank	B11G	43.5	44.8	3.0 %
Middelburg	B12C	19.0	17.7	-7.1 %
Loskop	B32A	153.0	156.5	2.3 %

Table 2.9 Final Analysis Results for Scenario H

2.3.8 Inter-basin transfers

This scenario was designed to test the WSAM results for a system with inter-basin transfers. Scenario VIII incorporates major dams Bronkhorstspruit, Witbank, Middelburg and Loskop with evaporation and natural hydrology. Four inter-basin transfer options were tested, each of which was analy sed as a separate scenario, as follows:

- Scenario VIII1: Based on Scenario I, with a transfer from Bronkhorstspruit Dam to Witbank Dam. The transfer capacity is 150 % of the Bronkhorstspruit yield (at the 98 % assurance).
- Scenario VIII2: Based on Scenario I, with a transfer from Bronkhorstspruit Dam to Witbank Dam. The transfer capacity is 200 % of the Bronkhorstspruit yield.
- Scenario VIII3: Based on Scenario I, with a transfer from Grootdraai Dam (in the upper Vaal River catchment) to Witbank Dam. The transfer capacity is 150 % of the Grootdraai yield.
- Scenario VIII4: Based on Scenario I, with a transfer from Grootdraai Dam to Witbank Dam. The transfer capacity is 200 % of the Grootdraai yield.

The final analysis results for Scenarios VIII1 to VIII4 are summarised in Table 2-10. It can be observed that WSAM generally underestimates the benefit of transferred water on the yield of the recipient catchment. In this regard it should be noted that WSAM does have the capability of modelling transfers in such a way that the yield benefit in the recipient catchment differs from the amount that is exported. This is achieved by changing the value of a transfer “Contribution Factor”, which is defined as the ratio [amount imported]/ [amount exported]. Because the contribution factor was set to 1, in the case of both Scenarios VIII1 and VIII2, a maximum transfer of only 23.3 million m3/a could be implemented (equal to the yield of Bronkhorstspruit Dam).

Dam name	Location (quaternary catchment)	WRYM Yield at 98 % assurance (million m^3/a)	WSAM Yield balance yYYBo (million m^3/a)	Difference (%)
Scenario VIII1 (Transfer capacity 150 % Bronkhorstspruit yield to Witbank)				
Bronkhorstspruit	B20C	24.0	23.3	-3.0 %
Witbank	B11G	80.5	74.6	-7.4 %
Middelburg	B12C	22.8	22.7	-0.5 %
Loskop	B32A	164.0	173.2	5.6 %
Scenario VIII2 (Transfer capacity 200 % Bronkhorstspruit yield to Witbank)				
Bronkhorstspruit	B20C	24.0	23.3	-3.0 %
Witbank	B11G	79.3	74.6	-6.0 %
Middelburg	B12C	22.8	22.7	-0.5 %
Loskop	B32A	167.1	173.2	3.6 %
Scenario VIII3 (Transfer capacity 150 % Grootdraai yield to Witbank)				
Bronkhorstspruit	B20C	24.0	23.3	-3.0 %
Witbank	B11G	251.0	241.9	-3.6 %
Middelburg	B12C	22.8	22.7	-0.5 %
Loskop	B32A	177.1	178.4	0.7 %
Grootdraai	C11L	188.4	190.6	1.2 %
C12L-dam	C12L	560.0	522.5	-6.7 %
Scenario VIII4 (Transfer capacity 200 % Grootdraai yield to Witbank)				
Bronkhorstspruit	B20C	24.0	23.3	-3.0 %
Witbank	B11G	251.0	241.9	-3.6 %
Middelburg	B12C	22.8	22.7	-0.5 %
Loskop	B32A	177.0	178.4	0.8 %
Grootdraai	C11L	188.4	190.6	1.2 %
C12L-dam	C12L	560.0	522.5	-6.7 %

Table 2.10 Final Analysis Results for Scenario VIII

3 Conclusion

As can be seen from the sections above, the final WSAM results compare well with WRYM for a variety of system configurations, each of which was designed to test a particular WSAM sub-model. Tests were undertaken with progressive complexity. Of all analyses undertaken, the results of 80 % indicated a difference between WSAM and WRYM smaller than 5 %. The remaining 20 % of the analyses indicated a difference in results of between 5 % and 10 %. The largest observed difference is 9.9 %. Many differences are related to the assumptions made in the development of the WSAM, in order to account for the spatial and temporal resolution of the model. It is therefore not unreasonable to expect small differences in the results of the two models. The results do indicate that WSAM is successful in reproducing WRYM results sufficiently accurately for preliminary analysis.

Combining this with the fact that the model processes the national dataset within seconds and requires very little effort to modify and run, makes it a very powerful tool that can play an important role especially at a reconnaissance analysis stage to select options for more detailed evaluation or for strategy development.

It is also a useful communication tool that can empower stakeholders to make well-informed decisions and understand the processes that affect water resources management. It encourages stakeholders to share information and to improve the existing national database and therefore assist with:

- decentralised water resource management by allowing various stakeholders to become more meaningfully involved in debates regarding the management of water resources,
- sharing of information and knowledge,
- broadening water resource management capacity by empowering people through improving their understanding of water resources management issues

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